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1. Project details

a. *Title*: *Development of a Renewable Energy-Based and Fully Grid Independent Radiant Air-Conditioning System*

b. *Institute*: *Indian Institute of Technology Ropar*

Aim / Objectives: The objectives of the research proposal are mentioned below,

i. Development of a grid-independent and energy efficient Radiant Cooling System (RCS)-based air-conditioning system to identify their potential to completely work with solar thermal (solar collector), solar Photo-Voltaic (PV), and biomass waste for small-scale applications (ranging 1 ton/3.5 kW to 2 tons/7.0 kW).

ii. Based upon their comparative assessment, design the optimized configuration operated with renewable energy resources (i.e., solar PV, solar thermal and biomass) that can attain the net zero status to the maximum possible extent for distinct climates of India.

iii. Comparison of the designed air-conditioning system with conventional (compression-based) and other (absorption) air-conditioning strategies aided by performance enhancement techniques, for instance, desiccant, cooling tower, evaporative cooler, Sensible Heat Recovery Wheel (SHRW) based on the performance (i.e., cooling demand/load), health aspects/indoor air quality, emissions and cost.

iv. Development and experimental investigation of the performance, emission and cost characteristics of the selected air-conditioning system under diverse operational and environmental constraints.

v. Formulation of an inverse optimization-methodology inspired from Artificial Intelligence (AI) soft computing tool to determine the optimized or suitable combinations of operational parameters of the designed air-conditioner under diverse cooling demand.

2. Executive Summary (*One page*):

The developed system is proposed to address various environmental concerns such as: global warming, energy crises, emissions, depletion of natural resources, poor agricultural waste management, and stubble burning etc. Additionally, this concept is also introducing the concept of high temperature cooling (i.e., Radiant Cooling System/RCS) under variable

climatic conditions with utilization of natural resources such as: solar, biomass etc. It is evident that as compared to conventionally used Vapor Compression Chiller (VCC), RCS design is more energy efficient with reduced ducting size, and it also offers better and healthier indoor air quality. The main characteristics of the proposed project contributing to the novelty aspect are discussed hereunder,

(1) The proposed RCS is fully grid-independent and will be operated by hybridization of solar (solar thermal and solar PV) and biomass energy resources.

(2) "Experimental" performance assessment by integrating the available VAC system to the RCS.

(3) Implementing theoretical minimum thermal load (TMTL) concept for personalized RCS cooling for energy efficiency, uniform thermal and better air quality.

(4) Development of AI-based methodology for assessing the necessary criteria to operate RCS under any dynamic/changing environmental condition (warm-humid, hot-dry and composite).

In the project, a test bench (see Fig. 1) including solar and biomass based resources has been developed by incorporating absorption-compression based chillers, desiccant assisted ventilation unit, radiant ceiling panels, solar thermal and photovoltaics, biomass gasifier, and other components. In this setup, system's electrical energy requirement is fulfilled through solar PV and biomass-genset, whereas thermal energy requirement is getting fulfilled by using solar thermal and biomass genset's waste heat recovery. Thus, the complete assembly is grid independent in nature. A portable test chamber is also fabricated to perform the experimental trails.

The proposed project focuses on the major issue of harmful pollution from the burning of agriculture wastes. Currently, the problem is very severe causing health issues in the northern part of India due to emission of harmful gases from such activities. In addition to this, the cooling demand in India is rising rapidly due to hot climate changes. The cooling requirements in the country are mainly dependent upon the conventional VCC driven by grid electricity. The generation of electricity is further contributing in the pollution due to usage of fossil fuels. The proposed project is of national interest and the work will be useful to cut down the electrical energy consumption and pollution levels. The expected payback period is expected to vary from 6-9 years depending upon the climatic conditions. Additionally, the associated emissions are very less compared to the conventional practices.

3. Scopes for further work

(i) The studied system can be assessed for other buildings, as well as integrated with different air conditioning technologies like complete VAC, supercritical CO_2, ejector cooling, etc.

(ii) The project also opens scopes for future development of ANN and other deep learning-based air-conditioning systems operated by renewable energy sources.

(iii) The current work was limited to compression-driven and IEC only, and the future work may be focused on the effects of absorption systems and other post-desiccant process air cooling methodologies by including heat wheel and direct expansion coils.

(iv) Currently most of the controlling mechanisms of the developed setup are manually driven. Future work in RCS can focus on enhancing energy efficiency, and thermal comfort by incorporating smart technology using AI-driven control, developing anti-condensation radiant materials, and integrating more sustainable functions for multi-functional building designs.

4. Benefits visualized

(i) The SHRW-based DOAS system showcased 9.6% of annual electrical energy savings compared to traditional cooling coil-based DOAS. Further, the system also reduced the net regeneration energy requirement by 28.1% compared to the traditional case. Further, the SHRW system demonstrated the energy savings up to 45.01% for tropical climate and 29.2% for Mediterranean climate.

(ii) The developed system was fully functioned by solar PV, solar collector and biomass gasification-based resources. During the summer season, the developed “grid-independent” RCS configuration was found to maintain the required thermal comfort conditions. In particular, the final indoor temperature was found to vary between 25.7°C-28 °C and relative humidity range of 44–56%.

(iii) During the winter season, the radiant system operated with indoor air temperature of 21.2 °C and relative humidity of approximately 60%.

(iv) Experimental study with the actual occupants shows the improvement in AQI with fresh air intake without compromising energy consumption. The final AQI with the proposed design strategy is around 97.

(v) ANN based model was capable of predicting around 70% of the forecasted data comprising cooling capacity, and vapor generator heating load between ±10% error margins

with respect to the exact out-sample data. The current approach therefore minimises the need for multiple experiments and conventional simulations involved in the design of a renewable energy-based radiant systems.

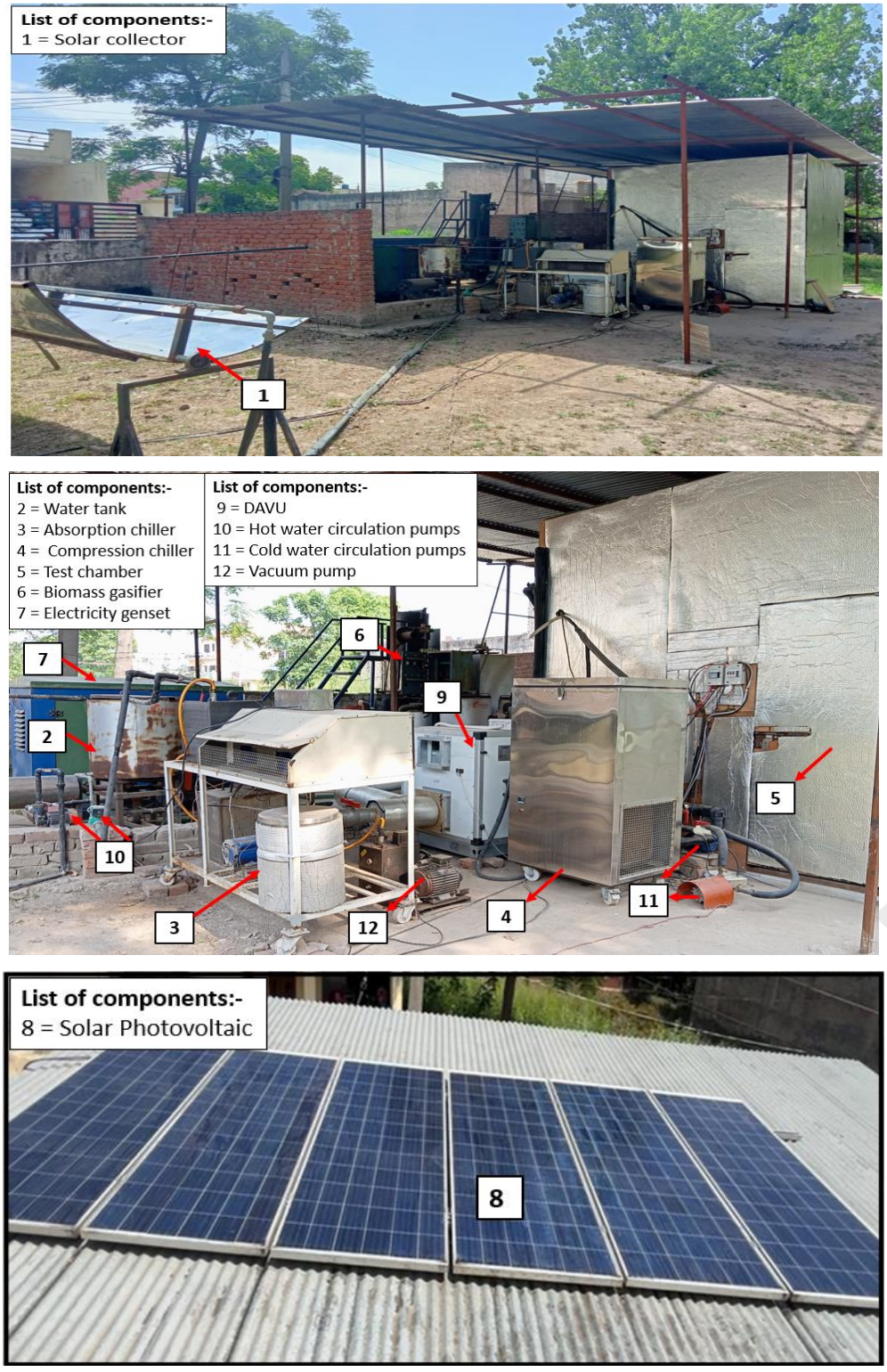

Figure 1: Photographs of the developed grid independent radiant cooling air-conditioning setup